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H1D
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(54) **Electron multiplier**

(57) A hollow elongate insulating body is divided longitudinally into separate parts (1,2) having discrete surfaces bearing dynodes (11 to 22) spaced along the hollow of the body. Each dynode is connected at an appropriate point to a chain of resistors connected in series and preferably sandwiched between the parts (1,2) of the body. A method of making the multiplier is also described.

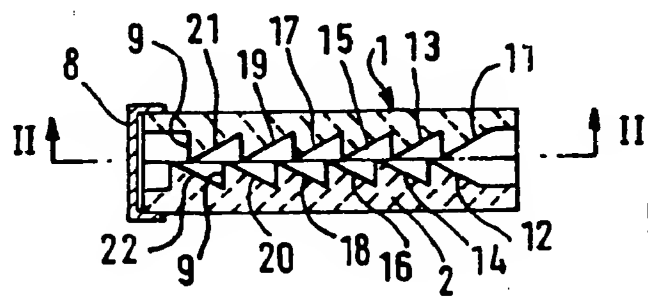

FIG.1.

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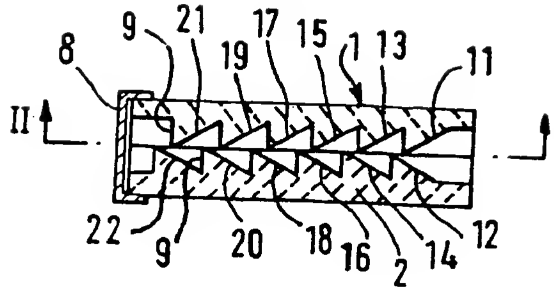

FIG.1.

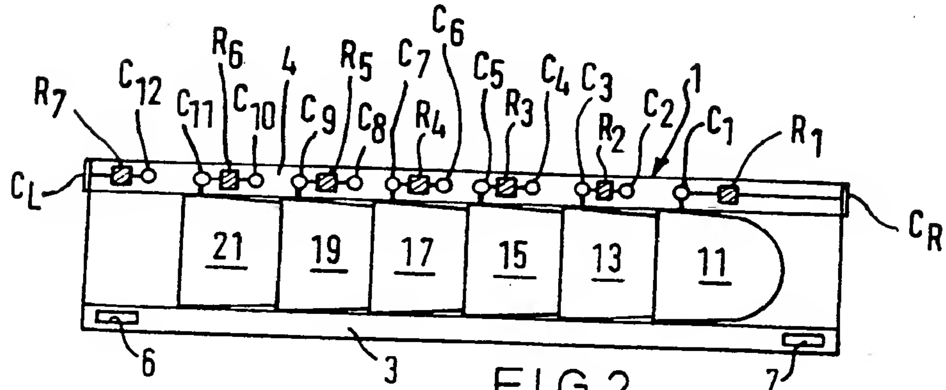

FIG.2.

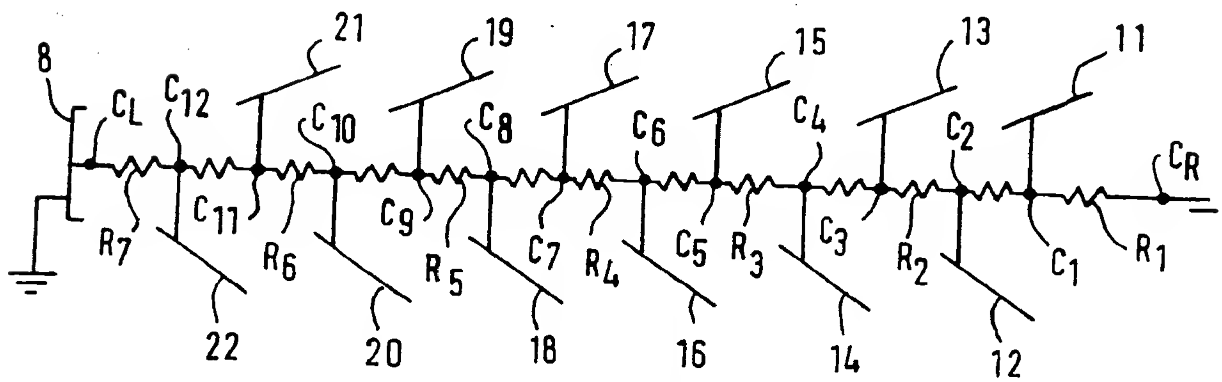

FIG.3.

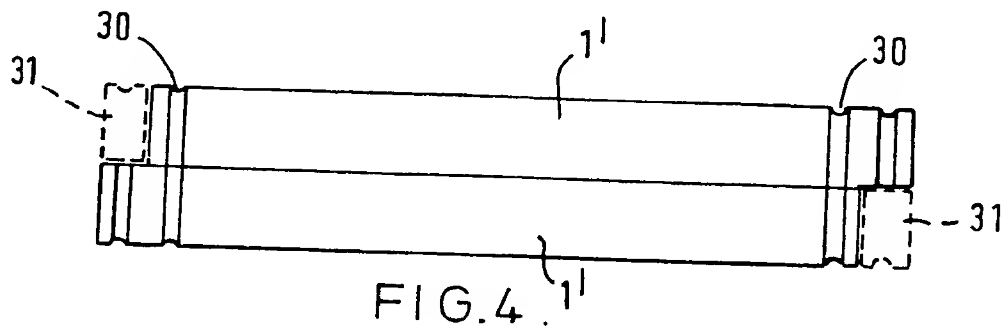

FIG.4.

SPECIFICATION

Electron Multiplier

This invention relates to electron multipliers, which are used to greatly multiply a primary electron flow.

An electron multiplier may, for example, be constructed as an ion multiplier, in which the primary electrons are released from a target impinged upon by a stream of ions. An ion multiplier is, for example, normally incorporated in a mass spectrometer. An electron multiplier may also be constructed as a photomultiplier, in which the primary electrons are emitted from a photocathode.

An electron multiplier comprises a number of dynodes, i.e. electrodes exhibiting the phenomenon of secondary emission. The primary electrons are attracted to and strike the first dynode of the chain. Secondary electrons emitted by the first dynode are attracted to the second dynode, and this sequence continues until the final dynode, which emits electrons which are collected by a collector. The first dynode is at a negative potential with respect to the second dynode, which is in turn at a negative potential with respect to the third dynode, etc. To provide the potentials required for all the dynodes, a resistor chain is provided, across which a large potential difference (e.g. 2 to 4 kV) is applied, usually between a large negative potential and earth potential, and the dynodes are each connected to an appropriate point in the chain, the potential difference between successive dynodes being, for example, 150 V.

Various designs of electron multipliers are available. In the so-called "Venetian Blind" type, oblique dynodes are stamped out of sheets which are stacked with spacers and interconnected by separate resistors. In the so-called "box and grid" type, bucket-shaped dynodes are mounted on plates which are again stacked with spacers. In the so-called "side cheek" or "fast tube" type, arcuate dynodes are individually mounted on rods extending between parallel side-walls. In each of these designs the dynodes are typically of beryllium copper alloy (BeCu) or silver magnesium (AgMg). They all have the disadvantage of complexity of construction. A simpler type of electron multiplier is known, comprising a tube of glass having a secondary emitting surface which functions both as the dynode chain and as the resistor chain, a large potential difference being applied along the tube, this type is inaccurate and its output is only proportional to its input within a limited range. It is also difficult to manufacture.

The present invention provides an electron multiplier having a chain of dynodes and a chain of resistors connected in series, each dynode being connected to the chain of resistors at an appropriate point, characterised by a hollow elongate insulating body divided longitudinally into separate parts having discrete dynode-bearing surfaces spaced along them within the hollow of the body.

Thus the electron multiplier of the invention is simple in construction but without any need to sacrifice accuracy in operation.

The dynode-bearing surfaces may be flat or concave. The dynodes are preferably provided as a coating on the said surfaces, the preferred coating technique being vacuum deposition; vapour deposition could also be used. The dynodes may be of any suitable material which can be surface-treated to provide secondary emission, one such material being BeCu. Preferably the dynodes are intercalated so that there is no free path for stray electrons along the axis of the body. On each longitudinal part of the body, the dynode-bearing surfaces may be alternate, oblique surfaces of a sawtooth configuration.

In a preferred embodiment the resistor chain is sandwiched between the longitudinal parts of the body. The resistor chain is preferably deposited on the insulating material of the body and any suitable resistive material may be used. Since it is sandwiched between the longitudinal parts of the body, the resistive material cannot produce spurious secondary emission, since it is not exposed to the electron flux in the hollow of the body. The resistor chain may comprise a single elongate coating of resistive material or discrete coatings of resistive material connected by coatings of conductive material (e.g. silver or gold). The resistor chain may be in direct contact with the dynodes or connected to them by branch conductors.

The invention also provides a method of making an electron multiplier as described above, in which separate longitudinal parts of the elongate hollow body, having discrete dynode-bearing surfaces, are formed from insulating material, and dynode-forming material is deposited on the said surfaces while the remaining surfaces are masked.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an axial section through an electron multiplier;

Figure 2 is an enlarged view on line II-II in Figure 1 of part of the electron multiplier;

Figure 3 is a circuit diagram of the electron multiplier;

Figure 4 is a side view of another embodiment of the body of the electron multiplier.

The electron multiplier illustrated has an elongate hollow body which is longitudinally subdivided (substantially along an axial plane) into two separate parts 1,2. Each part is separately moulded in a ceramic material which produces substantially no secondary emission. The parts 1,2 abut along intimately engaging joint faces 3,4 and have interengaging locating

holes 6 and projections 7. They can be held together by surrounding bands (not shown) or end caps; Figure 1 shows a conductive end cap 8 which serves as the collector.

Each part 1 (or 2) has a sawtooth formation providing transverse surfaces 9 substantially normal to the axis and oblique surfaces facing the opposite part 2 (or 1). Each oblique surface bears one of a chain of dynodes 11 to 22.

The dynodes may be formed on the parts in the following manner. A number of the parts are placed in a chamber and the surfaces other than the oblique surfaces which are to bear dynodes are masked by suitable screens. The chamber is evacuated and then BeCu is applied to the said oblique surfaces by vacuum deposition. Subsequently, in the same chamber, the BeCu deposit is treated to produce a surface which exhibits secondary emission.

On each of the longitudinal parts 1,2 one joint face 4 is provided with a sequence of conductors and resistors which match up to form a resistor chain connected to the dynodes 11 to 22. In Figure 2 the lines on the joint surface 4 diagrammatically represent conductors, the circles diagrammatically represent conductive contacts C_1, C_2, etc. for providing electrical connection between the opposed parts 1,2, and the shaded squares represent resistors R_1, R_2, etc.

The conductors, contacts, and resistors are applied to the joint surface 4 by vacuum deposition or any other convenient process. Preferably the conductors are deposited first, followed by the contacts C_1, C_2, etc. and then the resistors R_1, R_2, etc. or vice versa.

At one end of the resistor chain is connected to an end contact C_L, which connects the resistor chain to the (earthed) collector 8. At the other end the resistor chain is connected to an end contact C_R, which connects the resistor chain to a source of a large negative voltage either directly or *via* a photocathode (not shown) covering that end of the body. Electrons or ions entering the right-hand end of the hollow body (or electrons emitted from the photocathode) strike the first dynode 11, which emits secondary electrons which in turn strike the second dynode 12, and so on to the collector 8.

In Figure 1 the two parts 1,2 are not identical. Figure 4 shows an embodiment in which both parts 1′ are identical and can therefore be produced by a single mould. The staggering of the dynodes is achieved by offsetting the two parts 1′ longitudinally, the correct axial spacing being fixed by grooves 30 which are brought into register, as shown, to form circumferential grooves for receiving surrounding bands. The stepped ends of the body can be levelled off by grooved inserts 31, which can be used to carry electrodes, if desired.

The resistor chain can be divided up between the two parts 1′ so that they each have the same arrangement of resistors and conductors.

Various modifications may be made within the scope of the invention. For example: the dynode-bearing surfaces can be concave; the configuration of the conductors and resistors can be arranged differently; the collector may be provided as a coating within the body; the body need not be straight (e.g. it can be of arcuate or serpentine shape).

CLAIMS

1. An electron multiplier having a chain of dynodes and a chain of resistors connected in series, each dynode being connected to the chain of resistors at an appropriate point, characterised by a hollow elongate insulating body divided longitudinally into separate parts having discrete dynode-bearing surfaces spaced along them within the hollow of the body.

2. An electron multiplier as claimed in claim 1, in which the dynodes are constituted by a coating on the said surfaces.

3. An electron multiplier as claimed in claim 1 or 2, in which the dynodes are intercalated so that there is no free path for stray electrons along an axis of the body.

4. An electron multiplier as claimed in any of claims 1 to 3, in which, on each longitudinal part of the body, the dynode-bearing surfaces are alternate, oblique surfaces of a sawtooth configuration.

5. An electron multiplier as claimed in any of claims 1 to 4, in which the resistor chain is sandwiched between the longitudinal parts of the body.

6. An electron multiplier as claimed in any of claims 1 to 5, in which the resistor chain comprises a single elongate coating of resistive material.

7. An electron multiplier as claimed in any of claims 1 to 5, in which the resistor chain comprises discrete coatings of resistive material connected by coatings of conductive material.

8. An electron multiplier as claimed in any of claims 1 to 7, in which the body comprises identical longitudinal parts which are offset longitudinally with respect to each other.

9. A method of making an electron multiplier in accordance with any of claims 1 to 8, in which separate longitudinal parts of the elongate hollow body, having discrete dynode-bearing surfaces, are formed from insulating material, and dynode-forming material is deposited on the said surfaces while the remaining surfaces are masked.

10. A method as claimed in claim 9, in which the dynode-forming material is deposited by vacuum deposition or vapour deposition.

11. A method as claimed in claim 9 or 10, in which the resistor chain is deposited on the

body and is sandwiched between the longitudinal parts.

12. An electron multiplier substantially as described with reference to, and as shown in, Figures 1 to 3 or Figure 4 of the accompanying drawings.

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